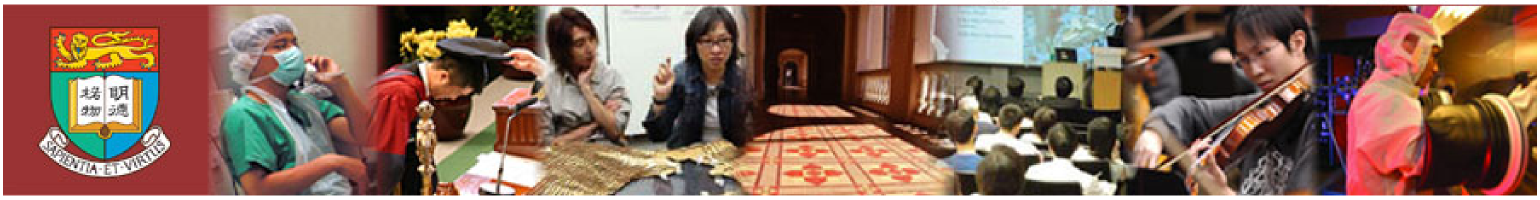

Title	Cantonese dichotic digit test: normative findings for children
Other Contributor(s)	University of Hong Kong.
Author(s)	Chiang, Lai-peng; 蔣麗萍
Citation	
Issued Date	2006
URL	http://hdl.handle.net/10722/50058
Rights	The author retains all proprietary rights, such as patent rights and the right to use in future works.

Cantonese dichotic digit test: Normative findings for children

Chiang Lai Peng

A dissertation submitted in partial fulfilment of the requirements for the Bachelor of Science (Speech and Hearing Sciences), the University of Hong Kong, May 3, 2006.

Abstract

There is little standardized test material currently available for the Hong Kong local population in relation to central auditory processing disorders (CAPD). The primary aim of the present study is to establish the norms for a Cantonese version of the Dichotic Digit Test (Cantonese DDT) − a commonly used assessment tool for screening and diagnosis of CAPD in western clinical practice. One hundred and twenty two Cantonese-speaking children aged between 6;00 to 11;11 years were examined with the Cantonese DDT under three listening conditions: free-recall, directed-left and directed-right ear. Age-specific normal cutoffs were developed using the criterion of two standard deviations below the means. The results revealed an age-related increase in overall performance. Significant right ear advantage (REA) was not consistently observed in all age groups. Further research on the Cantonese DTT is recommended to investigate its validity and reliability, and to study its performance on children with known auditory processing deficits.

Introduction

Hearing is a complex process which involves a series of transformations of sounds from the acoustic signals reaching our ears to the neural signals being analyzed by our brain. The ear has three parts: outer, middle and inner ears. Sounds waves are collected by the outer ear and transferred through the tympanic membrane to the middle ear. The acoustic signals are converted into mechanical stimuli by the tympanic membrane and amplified by three ossicles in the middle ear before entering the cochlea in the inner ear. The signals are then transformed into neural impulses in the cochlea and transmitted to the brain through the auditory nerve and the brain stem where auditory information is interpreted (Lysons, 1996). Central auditory processing disorder (CAPD) refers to conditions that affect one's auditory information processing, caused by the breakdown at any level of the complex neural pathways beyond the cochlea, despite normal hearing in the peripheral auditory system (Phillips, 1995).

Patients with CAPD often experience unusual difficulties in understanding speech under less than optimal listening conditions such as in noisy backgrounds, in reverberant environments, with distorted or rapid speech, and with competing speech. Some children with CAPD also have language and learning disabilities, most probably resulting from inefficient use of auditory information (Keith, 2001). According to the technical report of the American Speech-Language Hearing Association (ASHA) Task Force on Central Auditory Processing Consensus Development (2005), CAPD is defined as poor performance in one or more of these six behavioural phenomena: i) sound localization and lateralization; ii) auditory discrimination; iii) auditory pattern recognition; iv) temporal aspects of audition, including temporal integration, temporal discrimination (e.g. temporal gap detection), temporal ordering, temporal masking; v) auditory performance in competing acoustic signals, including dichotic listening; and

vi) auditory performance with degraded acoustic signals. According to Chermak and Musiek (1997), it was estimated that the prevalence of CAPD in children was between 2 to 3%.

A number of tests have been developed to evaluate CAPD over the years. Examples include dichotic listening tasks, temporal processes, binaural interaction tests and speech recognition using degraded (low redundancy) materials, according to Chermak and Musiek (1997). These tests challenge the auditory system to function under adverse listening situations in which patients with CAPD often encounter difficulties (Keith, 1999). Among the many central auditory test tools available, Musiek (1983) suggested that Kimura's Dichotic Digit Test (DDT; 1961), one of the common dichotic listening tasks, was a particularly appropriate central auditory assessment tool for the screening and diagnosis of CAPD. The DDT has high sensitivity to the auditory processing area in the brain and high test-retest reliability (Musiek et al., 1991). Moreover, DDT has good validity and offers good specificity and sensitivity for brainstem, cortical and subcortical dysfunction. It is simple and quick to administer and to score (Musiek, 1983; Chermak & Musiek, 1997; Strouse et al., 2000a).

The DDT is made up of different digits presented to both ears simultaneously. The subjects are then required to repeat the signals under three situations: free-recall, directed- right ear and directed-left ear listening conditions. The free-recall condition, in which the subjects were required to repeat the signals from both ears in any order of preference, has been used in earlier studies of dichotic listening tasks (Kimura 1961, 1963; Musiek 1983).

A right ear advantage (REA) phenomenon, referring to significantly higher scores for right ear than for left ear, was typically found in dichotic listening studies (Kimura, 1961; Molfese & Segalowitz, 1988). Left hemisphere dominance for language processing was claimed to be the cause of this finding. Bryden et al. (1983) argued that such REA performance could be affected by ear preference or attention bias which might not reflect true lateralization or hemispheric dominance. Hugdahl and Andersson (1986) then proposed a forced-attention paradigm in dichotic listening to study the interaction of attention with laterality. In forced-attention listening conditions, the participants will be instructed to repeat the test stimuli heard in one specific ear. Such procedures can help minimize the effect of selective attention. However, researchers still found that the REA was present in their subjects during the free-recall as well as during the forced listening conditions (Hugdahl & Andersson, 1986; Strouse et al., 2000a, 2000b). These findings have proven that the REA obtained in free-recall listening conditions is not solely the result of attention bias.

The interpretation of abnormal performance on dichotic listening tests, as proposed by Keith (2000), should be based on the following: i) poor overall performance; ii) reversal of ear advantage in different conditions (i.e., enhanced right ear advantage in the directed-right and enhanced left ear advantage in the directed-left listening conditions); and iii) a marked left ear advantage for both directed-right and directed-left conditions. Another criterion used to indicate CAPD is the presence of a larger REA and a significantly poorer left ear score than the normative values (Bellis, 2003; Chermak & Musiek, 1997). According to Keith (2000), abnormally poor overall performance or an abnormally large REA indicates delays in auditory maturation, underlying neurological disorganization or damage to auditory pathways. A marked left ear advantage for all test conditions indicates the possibility of damage to auditory reception areas of the left hemisphere or failure to develop left hemisphere dominance for language. It has also been claimed that these abnormalities are related to a wide range of specific learning difficulties, including CAPD, language, learning, and reading (Keith, 2000).

As an initial step to developing auditory processing assessment as a part of the scope of practice of audiology in Cantonese-speaking populations, the main objective of the present study was to develop the normative data for the newly developed Cantonese version of Dichotic Digit Test for children aged between 6;00 to 11;11 years. A double dichotic digit test, with two pairs of digits presented for each ear at the same time, was used in the present study. Bellis (2003) suggested that although single and triple dichotic digit tests are also available, double digit tests are the task of choice for the majority of children, because they are sufficiently challenging while remaining simple enough for younger listeners.

Determining the normative data is necessary for the development of a new test for the local population. Also, the need for developing DDT norms between the age range 6;00 to 11;11 is particularly crucial for the paediatric population because age specific normative values are required to make decisions on a child's auditory system, which is thought to be undergoing maturation during this period. Age specific norms enable clinicians to decide if a child differs from the other children at his/her age and to monitor a child's performance over time (Keith, 2000). Apart from developing the normative data, the effects of variables including age and gender in relation with this dichotic test were also investigated (Cowell & Hugdahl, 2000). Based on the previous findings, ear advantage was also a topic of interest in this research project.

In summary, the following issues would be investigated in the current study:

1. To develop age specific normative values of the Cantonese Double Dichotic Digit test for Hong Kong children, aged from 6;00 to 11;11.
2. To investigate if the current study evidenced significant REA within subjects

across the six age groups.

3. To compare the performance of different age groups through statistical analysis to determine if there were significant differences between age groups.
4. To compare gender group performance and determine through statistical analysis if it differed significantly.

Method

Participants

A total of 190 subjects from Primary grade1 to Primary grade 6 were recruited from four local schools in different districts to participate in this study. The socioeconomic status of the participants was evaluated by the median monthly domestic household income by district reported by Hong Kong Census and Statistics Department in 2001 Population Census. The monthly household income in the three districts where the four schools located ranged from $167500 to $25350, which reflects a reasonable variation when compared with the average income of $18705 across the whole territory (see Table 1). The average class size of the four schools was 32.5 students, which was comparable to the average class size (32.0) in Hong Kong in the years 2004/2005 cited in the report by the Committee on the Rights of the Child of the United Nations (2005). The background information of the schools is summarized in Table 1. Both right-handed and left-handed students were welcome for the study, yet none of the study group scored as strong left-handers in the Edinburgh Handedness Inventory (Oldfield, 1971). Informed consent was obtained from parents of all the participants.

TABLE 1. Background Information of the Participating Schools

School	Mode of Financing	Class size	Median monthly domestic household income by district
Hong Kong Island			
1. Central and West District			HK$ 25 350
• St. Anthony's Primary School	Aided school	34.4	
• Bonham Road Government Primary School	Government school	30.3	
New Territories			
2. Tsuen Wan District			HK$ 21 000
• Chiu Chow Public Primary School (A.M.)	Aided school	28.4	
3. Kwai Tsing District			HK$ 16 705
• Salesian Yip Hon Millennium Primary School	Aided school	35.5	

These subjects were interviewed and a case history was taken to ensure they fulfilling the following criteria: i) aged between 6;00 to 11;11 on the date of testing; ii) Cantonese as their first language; and iii) no unsuitable medical history (absence of brain/ear surgery, no regular medication, absence of long term middle ear infection). Among the 190 participants, nine were excluded because of failing one or more of the above criteria (see Table 2).

For the remaining 181 subjects, they proceeded to the next stage, involving hearing screening using otoscopy, pure tone audiometry and tympanometry. This was conducted to make sure that they fulfilled all the inclusion criteria: i) no signs of abnormalities in the external ear canals and tympanic membranes bilaterally; ii) bilateral normal hearing thresholds (<25 dB HL) at frequencies 500 Hz to 4000 Hz; and iii) bilateral normal middle ear function following the pass criteria set by ASHA (1990) (Peak Ytm: 0.3-1.4 cm^3.; Vea: 0.6-1.5 cm^3.; TW: 50-110 daPa).

All subjects passed the otoscopic screening but one failed the pure-tone screening. For the tympanometry screening, eight out of the 181 subjects (0.04%) had Type A_s tympanograms with the tympanometric compensated static acoustic admittance

(Peak Ytm) at less than 0.2 cm^3 and were hence excluded from the study (see Table 2). On the other hand, 68 out of the 181 subjects (37.57%) had their tympanograms with Peak Ytm at 0.2 cm^3, which was below the pass criteria of 0.3-1.4 cm^3 by AHSA (1990). However, according to Wan and Wong (2002), lower Peak Ytm values were often found in Southern Chinese subjects in their normative study. They suggested decreasing the lower limit of Peak Ytm to 0.2 cm^3 for the local Hong Kong Cantonese population. Therefore, those 68 subjects with Peak Ytm at 0.2 cm^3 were considered to pass the tympanometry screening in this study.

These 172 potential participants were also evaluated by using a teacher questionnaire, the Chinese version of the Screening Instrument for Targeting Educational Risk (the Chinese SIFTER; Li, 2003), to screen out children with hearing disability in school settings by their performance in five major domains: academics, attention, communication, class participation, and school behavior (Anderson, 1989). The participant's performance was compared with the normative data developed locally by Li (2003). Children who scored below the 10th percentile in any of the five subscales were excluded from the study and therefore 50 subjects were excluded.

TABLE 2. Details of the 68 students who failed the inclusion criteria

Inclusion criteria:	**Number of students failed the criteria:**	
Case history		
• aged between 6;00 to 11;11	5	(aged beyond 11;11 on the date of testing)
• Cantonese as the first language	1	(with Putonghua as his first language)
• suitable medical history	3	(2 under regular medication, 1 with present middle ear infection)
Screening		
• otoscopic examination	0	
• tympanometry	8	(fail the pass criteria by ASHA (1990) with Peak Ytm at less than 0.2 cm^3)
• pure-tone screening	1	(failed the screening with threshold > 25 dB)
C-SIFTER	50	(scored below the 10th percentile in any of the five subscales)

To sum up, 68 subjects were excluded by failing any of the inclusion criteria in the study. There were finally 122 subjects aged between 6;00 to 11;11 years, who had passed all the above inclusion criteria (64 males and 58 females) and were eligible to undertake the Cantonese Double Dichotic Digit Test (see Table 3).

TABLE 3. Demographic Data of the 122 participants eligible for DDT

Age groups (Year/Month)	Total number of students	Number of students: Male	Number of students: Female
6;00 to 6;11	18	9	9
7;00 to 7;11	18	11	7
8;00 to 8;11	19	7	12
9;00 to 9;11	17	11	6
10;00 to 10;11	27	15	12
11;00 to 11;11	23	11	12

Development of Cantonese Double Dichotic Digit Test

Test Stimuli: Fuente and McPherson (2005) developed the Cantonese version of Dichotic Digit Test, following the procedures described by Musiek (1983). The test stimuli were made up of a male voice reading digits 2 (/ji22/), 4 (/sɛi33/), 5 (/m35/), 6 (/lWk3/), 7 (/ts^{h}fɪt5/), 8 (/pat33/) and 9 (/kfɪu23/) spoken in Cantonese. These numbers were chosen because of their easily differentiable pronunciations. 1 (/jfɪt5/) was excluded because its rime sound is similar to that of 7 (/ts^{h}fɪt5/); 3 (/sam55/) and 10 (/sfɪp2/) were also excluded due to their similar onset sounds with that of 4 (/sɛi33/). Test materials comprised one practice CD and three CDs for actual testing. The practice CD recorded nine practice sets with three practice trials for the use in three conditions: free-recall (FR), directed-left (DL) and directed-right (DR). The three CDs for actual testing recorded 20 sets of digits each for the three conditions. Each set of stimuli contained four digits, in which each pair of two digits were presented to each ear simultaneously.

Stimuli Presentation: A preparation alert “請準備” (*“please get ready”*) was played before the presentation of the two pairs of digits. There was one second of silence before the presentation of first pair of digits. 0.5 seconds of silence then followed before the second pair of digits was presented. An inter-stimuli interval of five seconds was inserted between stimuli sets to allow adequate response time.

Materials and Procedures

i) Case History Taking. Consent to participate in the study were obtained from all the parents. All subjects were interviewed and case history was taken to ensure that they fulfilled the criteria of target age range, Cantonese as the first language, and no unsuitable medical history. Besides, five questions concerning their handedness extracted from the Edinburgh Handedness Inventory by Oldfield (1971) were also used. Five questions included the participants’ preference of hands when writing, drawing, throwing, using toothbrush and using a spoon.

ii) Hearing Screening. Testing was done in sufficiently quiet rooms at the schools. A manual WelchAllyn otoscope was used in the otoscopic examination to reveal any external ear canal or tympanic membrane abnormalities bilaterally. Middle-ear function was evaluated using the GSI 37 Auto Tymp. Pure-tone screening was performed using the Madsen Micromate 304 portable screening audiometer equipped with ME 70 noise-excluding headset. The pure-tone audiometry was conducted at 25 dB HL at 500 Hz, 1000 Hz, 2000 Hz, and 4000 Hz to ensure the participants had normal hearing thresholds (0 to 25dB HL). The results of the hearing screening were explained to the participants at the end of the test. A hearing screening form was given to each participant for future reference.

iii) The Chinese SIFTER. The class teachers of the participants were required to complete the questionnaire of the Chinese version of the Screening Instrument for Targeting Educational Risk (the Chinese SIFTER) (Li, 2003). The Chinese SIFTER is a 15-question teacher-report screening tool, was used to screen out children with possible hearing disability in school settings. Since people with CAPD may have normal peripheral hearing sensitivity, pure-tone audiometry and tympanometry cannot screen out subjects with CAPD. Therefore, the Chinese SIFTER was adapted to screen out children who are experiencing listening difficulties and at risk for learning difficulties in which patients with CAPD often encounter (Anderson, 1989). It captures five major domains in which hearing-impaired children are at risk for developing problems: academics, attention, communication, class participation, and school behavior. Responses are on a rating scale (1-5) that categorizes each student as upper, middle, or lower range for each item. Descriptors for the numerical ratings vary for each item and appear in each section. The classroom teachers would compare the rated student's performance with the "average" student in the class, and rate each question with a score that best describes the student's function in the classroom. Children who scored below the 10th percentile in any of the five subscales were excluded from the study.

iv) The Cantonese Double Dichotic Digit Test. The CDs containing the test stimuli were played by a Sony CD player model D-365 connected to a Madsen Itera II Diagnostic Audiometer, which can set the output signals presented constantly at 60 dB HL. The stimuli were binaurally presented through Telephonics TDH-39P headphones connected to the Audiometer. All participants started with the free-recall condition (FR) first. They were then assigned randomly to do the directed-right (DR) or directed-left

(DL) as the second and third task. For the FR condition, the participants were instructed to repeat all four digits heard in both ears in any order. For the directed listening tasks, the participants were instructed to repeat the digits heard in the specified ear only. Three practice trials in the practice CD were used before the actual testing for each condition to ensure task understanding before proceeding to the real test. The 20 stimuli sets in each of the three CDs were presented randomly by using the "shuffle" function in the CD player. The participants were encouraged to guess when uncertainty of a response occurred. The instructions for DDT were shown in Appendix A.

v) Calculating Scores for Cantonese Double Dichotic Digits Tests. The participants' responses were recorded on the scoring form. A correct response was allocated to the digit that was repeated correctly, irrespective of the order. The right ear score (RE) and left ear score (LE) defined as the percentage of correctly repeated digits in the right ear and left ear respectively were computed for each of the three dichotic listening conditions. Ear advantage (EA) values for each test condition were calculated by RE minus LE divided by the sum of LE and RE, and expressed as percentage (100*RE-LE/RE+LF). A positive value indicated a right ear advantage (REA) while a negative value represented a left ear advantage (LEA).

Results

Descriptive Statistics

Mean, standard deviation and range

The mean (expressed as %), standard deviation and range for left ear (LE), right ear (RE) and ear advantage (EA) scores for each test condition were computed. The results for the six age groups are illustrated in Table 4. For the FR condition, LE and RE scores for the age groups from 6 to 11 were illustrated in Figure 1. The LE scores for the directed-left (DL) and RE scores for the directed-right (DR) conditions across age groups are illustrated in Figure 2.

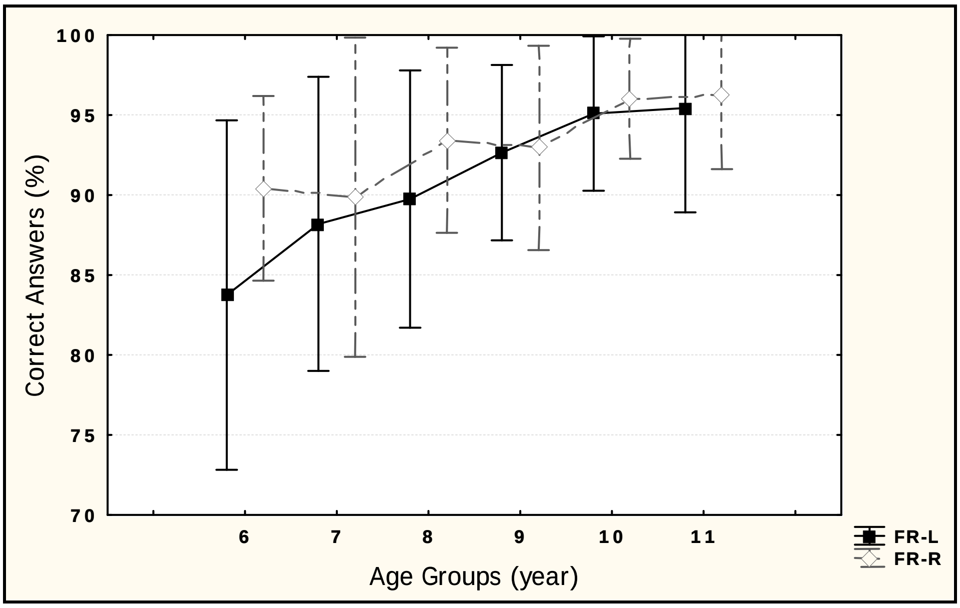

Figure 1. Correct answers (mean±1 SD) for left ear (LE) and right ear (RE) for the six age groups in free-recall (FR) condition.

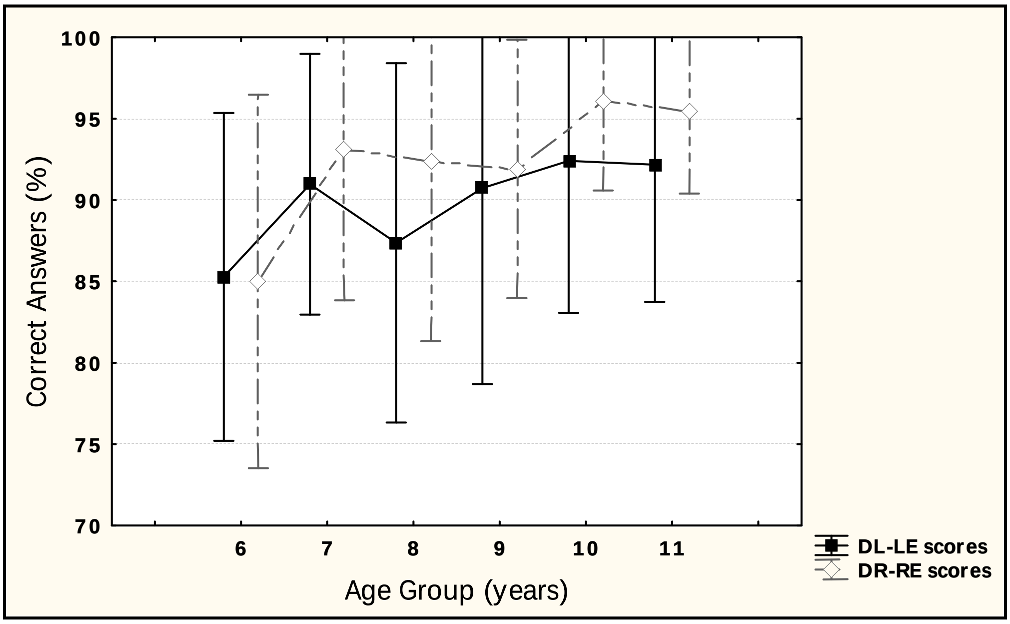

Figure 2. Correct answers (mean±1 SD) for left ear (LE) and right ear (RE) for the six age groups in directed-left (DL) and directed-right (DR) conditions, respectively.

TABLE 4. Mean (%), Standard Deviation, and Range for the DDT under Three Testing Conditions (free-recall, directed-left and directed-right) in Six Age Groups

Age Group 6-6;11 (N=18)

	Left Ear				Right Ear				Ear Advantage			
	Mean	SD	Min	Max	Mean	SD	Min	Max	Mean	SD	Min	Max
FR	83.75	10.92	60.00	97.50	90.42	5.77	80.00	100.00	4.14	7.07	-5.56	20.00
DL	85.28	10.07	70.00	100.00	14.44	9.65	0.00	30.00	-70.97	19.50	-100.00	-40.00
DR	15.00	11.47	0.00	37.50	85.00	11.47	62.50	100.00	70.00	22.94	25.00	100.00

Age Group 7-7;11 (N=18)

	Left Ear				Right Ear				Ear Advantage			
	Mean	SD	Min	Max	Mean	SD	Min	Max	Mean	SD	Min	Max
FR	88.19	9.19	67.50	97.50	89.86	9.98	57.50	100.00	0.88	7.01	-20.69	11.48
DL	90.97	8.00	70.00	100.00	8.89	8.05	0.00	30.00	-82.21	16.10	-100.00	-40.00
DR	6.94	9.22	0.00	30.00	93.06	9.22	70.00	100.00	86.11	18.44	40.00	100.00

Age Group 8-8;11 (N=19)

	Left Ear				Right Ear				Ear Advantage			
	Mean	SD	Min	Max	Mean	SD	Min	Max	Mean	SD	Min	Max
FR	89.87	8.25	65.00	100.00	93.33	5.94	80.00	100.00	2.01	4.15	-4.00	16.13
DL	87.78	11.21	52.50	100.00	12.08	11.12	0.00	47.50	-74.95	21.95	-100.00	-5.00
DR	7.64	11.13	0.00	40.00	92.22	11.34	60.00	100.00	84.66	22.35	20.00	100.00

Age Group 9-9;11 (N=17)

	Left Ear				Right Ear				Ear Advantage			
	Mean	SD	Min	Max	Mean	SD	Min	Max	Mean	SD	Min	Max
FR	92.65	5.48	80.00	100.00	92.94	6.39	77.50	100.00	0.13	3.07	-7.46	4.00
DL	90.74	12.05	55.00	100.00	9.56	12.00	0.00	45.00	-80.94	23.99	-100.00	-10.00
DR	7.94	8.02	0.00	25.00	91.91	7.93	75.00	100.00	84.11	16.03	50.00	100.00

Age Group 10-10;11 (N=27)

	Left Ear				Right Ear				Ear Advantage			
	Mean	SD	Min	Max	Mean	SD	Min	Max	Mean	SD	Min	Max
FR	94.31	4.99	80.00	100.00	96.11	3.95	87.50	100.00	1.11	2.05	-2.70	5.00
DL	90.97	9.86	67.50	100.00	9.03	9.86	0.00	32.50	-81.94	19.71	-100.00	-35.00
DR	3.33	4.29	0.00	15.00	96.67	4.29	85.00	100.00	93.33	8.57	70.00	100.00

Age Group 11-11;11 (N=23)

	Left Ear				Right Ear				Ear Advantage			
	Mean	SD	Min	Max	Mean	SD	Min	Max	Mean	SD	Min	Max
FR	95.00	7.17	70.00	100.00	96.25	5.09	82.50	100.00	0.74	2.73	-4.00	8.20
DL	93.06	7.15	72.50	100.00	6.94	7.15	0.00	27.50	-86.11	14.30	-100.00	-45.00
DR	4.17	4.93	0.00	12.50	95.83	4.93	87.50	100.00	91.67	9.85	75.00	100.00

Key: FR=Free-recall condition, DL=Directed-left condition, DR=Directed-right condition

Percentile scores

According to the scores of the participants, the percentile profiles (5th, 10th, 25th, 50th, 75th, 90th, 95th) are developed for the LE and RE scores for the three conditions (see Table 5).

TABLE 5. Percentile Table for the DDT Scores in Three Testing Conditions

	Age 6-6;11				**Age 7-7;11**				**Age 8-8;11**			
	FR-L	**FR-R**	**DL-L**	**DR-R**	**FR-L**	**FR-R**	**DL-L**	**DR-R**	**FR-L**	**FR-R**	**DL-L**	**DR-R**
5th	64.25	82.13	70.00	68.88	67.50	76.63	76.38	72.13	74.00	80.00	68.25	73.50
10th	68.50	84.25	70.00	70.00	74.50	81.75	81.00	77.75	83.00	88.00	78.00	77.00
25th	78.13	85.00	78.75	77.50	85.00	85.63	87.50	95.00	90.00	91.25	85.00	91.25
50th	88.75	90.00	87.50	87.50	91.25	93.75	92.50	96.25	90.00	95.00	90.00	95.00
75th	90.00	94.38	91.88	93.75	94.38	95.00	95.00	97.50	93.85	97.50	93.75	100.0
90th	95.00	97.50	97.50	100.00	97.50	98.25	100.0	100.0	97.50	100.0	95.50	100.0
95th	95.38	97.88	97.88	100.00	97.50	100.0	100.0	100.0	97.75	100.0	97.75	100.0
	Age 9-9;11				**Age 10-10;11**				**Age 11-11;11**			
	FR-L	**FR-R**	**DL-L**	**DR-R**	**FR-L**	**FR-R**	**DL-L**	**DR-R**	**FR-L**	**FR-R**	**DL-L**	**DR-R**
5th	84.00	81.50	65.00	79.00	87.50	90.00	71.50	85.00	85.75	87.75	73.50	87.50
10th	86.50	85.50	78.00	81.50	89.00	91.50	78.00	88.00	92.50	90.50	82.50	87.50
25th	90.00	90.00	90.00	87.50	92.50	92.50	88.75	93.75	95.00	95.00	88.75	92.50
50th	92.50	92.50	95.00	92.50	95.00	97.50	97.50	97.50	97.50	97.50	95.00	97.50
75th	97.50	97.50	97.50	100.0	98.75	100.0	98.75	100.0	98.75	100.0	97.50	100.0
90th	98.50	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
95th	100.00	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Key: FR-L=Free-recall condition-left ear, FR-R=Free-recall condition-right ear
DL-L=Directed-left condition-left ear, DR-R=Directed-right condition-right ear

Inferential Statistics

Similar to the previous findings (Hällgren et al., 2001), ceiling or near ceiling effects were revealed in the present study. Therefore, nonparametric tests were used for inferential analysis.

Ear differences

The differences between the left ear and right ear scores within subjects were evaluated statistically using Wilcoxon’s matched pairs test. Comparisons were done separately for the six age groups, the free-recall condition, and directed-recall conditions. For the directed-recall conditions, left ear scores in directed-left (DL-L) were compared with right ear scores in directed-right (DR-R) and EA was computed between these two scores. For the free-recall condition, significant right ear advantage (REA) was observed in the age groups 6-6;11 and 8-8;11 (p<.05). For the directed-recall conditions, significant REA was observed in age groups 8-8;11 and 11-11;11 instead (p<.05) (see Table 6).

TABLE 6. Means (%) for Left Ear, Right Ear and Ear Advantage Scores in the DDT, and the Significant *p*-level for Ear Advantage Within-subjects under Free-recall and Directed-recall Conditions

	Free-recall Condition				Directed-recall Condition			
Age Group	**FR-L**	**FR-R**	**FR-EA**	***p*-level (FR-EA)**	**DL-L**	**DR-R**	**EA**	***p*-level (EA)**
6-6;11	83.75	90.42	4.14	.025**	85.28	85.00	-0.27	.879
7-7;11	88.19	89.86	0.88	.307	90.97	93.06	1.07	.170
8-8;11	89.87	93.33	2.01	.022**	87.78	92.22	2.52	.008**
9-9;11	92.65	92.94	0.13	.675	90.74	91.91	0.97	.670
10-10;11	94.31	96.11	1.11	.179	90.97	96.67	3.27	.052
11-11;11	95.00	96.25	0.74	.514	93.06	95.83	1.55	.047**

*****p-level < .05***
Key: FR-L=Free-recall condition-left ear, FR-R=Free-recall condition-right ear
DL-L=Directed-left condition-left ear, DR-R=Directed-right condition-right ear
EA=Ear advantage

Age group comparisons

Age was considered as the between-group factor. The age effects in DDT were studied using a Kruskal-Wallis one-way ANOVA by ranks in the free-recall condition (FR-L, FR-E and FR-EA) and directed-recall conditions (DL-L, DR-R, and EA between them). Significant groups differences were found in FR-L [H (5,122) = 34.21, p<.0001], FR-R [H =18.67, p<.003], DL-L [H = 14.79, p<.03] and DR-R [H = 14.96, p<.02], but not FR-EA [H = 6.99, p=.22] and EA between DL-L and DR-R [H = 5.87, p=.319). The significant differences derived from this test only suggested that at least one group differed from the others. Post hoc multiple comparisons of mean ranks for all age groups were, therefore, conducted to determine exactly which groups differed from the others. Significant group differences were found only in FR-L, FR-R and DR-R but not DL-L in the post hoc comparisons. For FR-L, age groups 6-6;11 and 7-7;11 were found to score significantly lower than 10-10;11, and the scores for 6-6;11, 7-7;11 and 8-8;11 were significantly lower than 11-11;11. For FR-R, age group 6-6;11 was significantly different to 10-10;11 and 11-11;11. For DR-R, there was significant difference between age group 6-6;11 and 10-10;11. The results for significantly different between-group comparisons are summarized in Table 7.

Table 7. The Significant *p*-level Between Age Groups Under Free-recall and Directed-recall Conditions

	Between Groups	***p*-level**	**Between Groups**	***p*-level**
FR-L	6-6;11& 10-10;11	.000**	7-7;11 & 10-10;11	.040**
	6-6;11 & 11-11;11	.000**	7-7;11 & 11-11;11	.008**
	8-8;11 & 11-11;11	.027**		
FR-R	6-6;11 & 11-11;11	.026**	6-6;11 & 10-10;11	.012**
DL-L	--	--	--	--
DL-R	6-6;11 & 10-10;11	.006**		

*****p-level<.05***
Key: FR-L=Free-recall condition-left ear, FR-R=Free-recall condition-right ear
DL-L=Directed-left condition-left ear, DR-R=Directed-right condition-right ear

<u>Gender comparisons</u>

A nonparametric Mann-Whitney *U* test was used to investigate the two gender groups in the free-recall condition (FR-L, FR-E and FR-EA) and directed-recall conditions (DL-L, DR-R, and EA between them) for each age group independently. No significant gender differences were found in all conditions except the FR-R and DR-R in age group 8-8;11 (*p*<.04 for FR-R and *p*<.02 for DR-R).

Discussion

The primary purpose of the present study was to develop a Cantonese version of the Double Dichotic Digit test, and to determine its age specific normative values for Hong Kong children. The test's relationships to some fundamental variables, including ear difference, age group difference and gender difference were also investigated.

The norms

Many studies have shown that central auditory processing in young children is less efficient than that of adults (Chermak & Musiek, 1997). As explained before, the ongoing development of the auditory system in paediatric populations is reflected in the age-related increase in overall performance in CAPD tests. Therefore, age specific norms were developed for ages 6 to 11.

Neijenhuis (2004) suggested that percentile scores should be applied to facilitate the interpretation of auditory processing tests. It was also suggested that when a normal distribution was not demonstrated, the use of cutoff scores is preferred to be set at the 10th percentile. Those who score below the 10th percentile would be, therefore, considered to be abnormal (Neijenhuis, 2001, 2004). Yet Bellis (2003) recommended another criterion to determine the cutoff for normality, by using two standard deviations (SDs) below the mean scores. In our present study, the cutoff scores calculated using these two criteria for the left ear and right ear, in the three testing conditions, were presented in Table 8.

In reviewing the English version for the Double Dichotic Digits Test, the age specific normal cutoffs for age range 7-11;11 and 12 to adults developed by Musiek (Dartmouth-Hitchcock Medical Center) cited in Bellis (2003) were also listed in Table 8. However, left and right ear scores were only available for the free-recall condition.

Bellis (2003) advised that clinicians were strongly urged to collect their own age-appropriate normative data for DDT for their local population, as they should do with all other tests of central auditory function. The norms for the English version would hence only serve as a comparative reference for the present study.

TABLE 8. The Age Specific Normal Cutoff Scores (%) Calculated as Below the 10th Percentile and Two SDs below the Means of the Present Study, and English norms (2 SDs below the mean)

Age Group	Below 10th Percentile				2SDs Below Mean				English norms (2 SDs Below Mean*)	
	FR-L	**FR-R**	**DL-L**	**DR-R**	**FR-L**	**FR-R**	**DL-L**	**DR-R**	**FR-L**	**FR-R**
6 -6;11	68.50	84.25	70.00	70.00	61.90	78.88	65.14	62.06	--	--
7-7;11	74.50	81.75	81.00	77.75	69.82	69.90	74.96	74.62	55	70
8-8;11	83.00	88.00	78.00	77.00	73.37	81.45	65.36	69.54	65	75
9-9;11	86.50	85.50	78.00	81.50	81.68	80.16	66.64	76.05	75	80
10-10;11	89.00	91.50	78.00	88.00	84.33	88.21	71.26	88.09	78	85
11-11;11	92.50	90.50	82.50	87.50	80.65	86.07	78.75	85.98	88	90
12-adults	--	--	--	--	--	--	--	--	90	90

* ***Bellis (2003)***
Key: FR-L=Free-recall condition-left ear, FR-R=Free-recall condition-right ear
DL-L=Directed-left condition-left ear, DR-R=Directed-right condition-right ear

From Table 8, the criterion of using below the 10th percentile as the normal cutoffs is more conservative than that of two standard deviations below the mean. On the other hand, it shows that the cutoff scores calculated by using two SDs below the mean for the present study is more comparable to the standard suggested by Musiek. The overall cutoff scores calculated in the present study were, however, higher than Musiek's suggested cutoffs. To evaluate which criterion is more suitable for our population, the numbers of subjects who failed the test under these two criteria were computed and shown in Table 9.

TABLE 9. The Numbers of Subjects Who Failed the Cutoff Scores (%) under the Criteria of Below the 10th Percentile and Two SDs below the Means for the Present Study

		Below 10th Percentile		2 SDs Below Mean	
Age group	**Sample size (N)**	**No. of failed subjects (%)**		**No. of failed subjects (%)**	
6 -6;11	18	5	27.78%	1	5.56%
7-7;11	18	5	27.78%	4	22.22%
8-8;11	19	3	15.79%	3	15.79%
9-9;11	17	5	29.41%	3	17.65%
10-10;11	27	8	29.63%	4	14.81%
11-11;11	24	3	12.50%	3	12.50%

As shown in Table 9, the percentage of subjects failing the cutoff scores of below the 10th percentile was considered to be rather high (average=23.82%). As the 122 subjects recruited for the present DDT study had passed all the inclusion criteria which already covered a range of abilities (e.g., first language, medical history, peripheral hearing, academics, attention, communication, class participation, and school behavior), the probability for them to have suspected CAPD should be rather low. Yet the failure rate was still surprisingly high using the 10th percentile criteria. This criterion is thus considered to be too conservative. For the other criterion of using two SDs below the means, the average failing rate is 14.76% for the present study. Therefore, the author recommends using the criterion using cutoffs at two SDs below the means, which was suggested by Bellis (2003), for the age-specific cutoff scores in the present study.

Ear difference

Positive ear advantage (EA) scores were found in both the free-recall and directed-recall listening conditions across the six age groups except the directed-recall condition for age group 6-6;11 as shown in Table 6. A positive EA score represents an average right ear advantage (REA) between ears. However, only the age groups 6-6;11 and 8-8;11 demonstrated significant REA in free-recall condition while age groups 8-

8;11 and 11-11;11 showed significant REA in directed-recall conditions (see Table 6). Despite Kimura (1961) reporting significant REA for all age groups in her study, another study by the same author in 1963 and other studies quoted in Molfese and Segalowitz (1998) reported similar findings as in the present study - that significant REA was not consistently observed in all age groups.

Across age groups, the EA ranged from -5.56 to 20.00% in the age group 6-6;11 (average=4.14) while the EA decreased to range from -4.00 to 8.20% in the age group 11-11;11 (average=0.74) in the free-recall condition. Such reduction in EA ranges coincided with previous reports that a minimum right-left ear difference similar to adult performance is achieved by about 11 to 12 years of age (Keith, 2000). However, significant differences were not found across age groups for the EA in the free-recall condition (FR-EA) (p=0,22), nor for the EA compared between the two directed-recall conditions (p=.319) using a Kruskal-Wallis one-way ANOVA test. This is in agreement with many earlier studies cited in Molfese and Segalowitz (1998) that no developmental change in EA was found in dichotic listening tests.

Age groups difference

As illustrated in Figure 1 and Figure 2, an overall increasing trend was shown across the age groups until it started to level off at age 10 to 11;11. Such phenomenon was observed in left ear and right ear scores under both the free-recall and directed-recall conditions. These findings were similar to previous findings which have suggested that DDT performance reaches a plateau around adolescence (Keith, 2000).

When looking at the inferential statistical analysis, results suggested that the younger age groups (age 6-6;11, age 7-7;11 and age 8-8;11) generally yielded significantly lower scores than the older age groups (age 10-10;11 and age 11-11;11) (see Table 7). Age effects were found in the left scores in free-recall condition, right ear scores in free-recall and directed-right conditions. Such findings in the present study supported the previous claim by Keith (2000) that the auditory system is undergoing maturity in children and an age-related increase is expected for the overall performance in the DDT. Age effects in the DDT have also been previously reported by Hällgren et al. (2001), Jaffe (1996; cited in Hällgren et al., 2001) and Martin and Cranford (1991; cited in Hällgren et al., 2001).

Gender difference

No significant gender differences were found any conditions except the FR-R and DR-R in age group 8-8;11 (p<.04 for FR-R and p<.02 for DR-R), in which the female group scored significantly higher for their right ears in free-recall and directed-right conditions. According to Harlpern (2000), Philip (1987), and Zaidel et al. (1995), gender effects were not consistently demonstrated in dichotic listening tests. The unexpected gender differences in age group 8-8;11 found in the present study might be related to the unequal sample sizes for the two genders in this age group (seven males and twelve females).

Clinical Implications

Musiek and Pinheiro (1985; cited in Chermak & Musiek, 1997) suggested that dichotic listening tests are clinically useful because dichotic tasks in general are sensitive to central auditory dysfunction. It was also advised that a dichotic speech test should be strongly considered for inclusion in a central test battery. Currently, a limited range of standard screening tools for CAPD are available in Hong Kong. As explained in the introduction part, the Cantonese Double Dichotic Digit Test could be a useful and practical clinical test to identify patients with suspected CAPD. It is therefore advisable to include this Cantonese version of DDT as one of the tests in a locally developed central auditory processing assessment package.

The present study on the DDT sampled 122 primary school children without hearing loss, academic or behavioral problems reported by their class teachers. The performances of these children should represent a typical population of primary school students in Hong Kong. Hence, the normative values developed in this study may serve as a useful reference for comparing patients with suspected CAPD in clinical use. With appropriate assessment and follow-up treatment, individuals confirmed with CAPD can still become skilled listeners who regulate and guide their listening and extraction of information from the spoken message (Chermak & Musiek, 1997).

Limitations of the Present Study and Directions for Future Research

Although the validity and reliability of the English version of DDT have been well reported in the corresponding western literature (Musiek, 1983; Chermak & Musiek, 1997; Musiek et al., 1991; Strouse et al., 2000a), the validity and reliability of the Cantonese version of DDT was not investigated in the present study. According to ASHA (1997), the usefulness of a test depends on its reliability, validity, sensitivity, responsiveness, specificity and feasibility. Further research should be done to investigate these areas for the Cantonese version.

Besides, although the present study sampled a large number of normal primary school children, children with known auditory processing deficits such as children with suspected CAPD, learning disability or known hemispheric pathology were not sampled. Therefore, further research may investigate the performance of this population which can also help review the normative data developed in the present study.

It would have been preferable to investigate the relationship between DDT and other tests for CAPD. In the meantime, it is also advisable to develop Cantonese versions for other CAPD tests. A battery of CAPD tests provides information on different aspects of auditory functions such that it is more informative than a single test (Neijenhuis et al., 2001). Further research may aim at constructing a local battery consisting of several CAPD tests.

Conclusion

The present study reported the development of the Cantonese version of Double Dichotic Digit Test − a useful and easily administered test for detecting central auditory processing disorders. Age-specific cutoff scores were developed for the age range 6;00 to 11;11 under free-recall and directed-recall conditions. An age-related increase in overall performance was demonstrated. This finding was explained by the undergoing maturity of auditory system in paediatric population. Yet no developmental change was found in ear advantage. Significant REA was not consistently observed in all age groups under the free- and directed-recall conditions. No gender effects were observed. It is hoped that this preliminary development and investigation of the Cantonese DDT will help in the detection and follow up children with CAPD. Further research is needed to investigate the validity and reliability of this Cantonese CAPD test. Children with known auditory processing deficits should also be studied with this test.

Acknowledgement

The author would like to express sincere thanks to Dr. Bradley McPherson for his kind guidance and support. The author would also like to thank all the participating schools, teachers and children for their participation and assistance. Special thanks were delivered to the fellow classmates from the Division of Speech and Hearing Sciences, The University of Hong Kong, for their support and help during the course of this study.

References

American Speech-Language-Hearing Association (ASHA). (2005). *(Central) auditory processing disorders: Working group on auditory processing disorders*. Retrieved April 7, 2006 from the ASHA website http://www.asha.org/NR/rdonlyres/8404EA5B-8710-4636-B8C4-8A292E0761E0/0/v2TR_CAPD.pdf

American Speech-Language-Hearing Association Audiologic Assessment Panel. (1997). *Guidelines for audiologic screening*. Rockville, MD: Author.

Anderson, K.L. (1989). *Screening Instrument for Targeting Educational Risk (SIFTER).* Little Rock, AR: Educational Audiology Association.

Bellis, T. J. (2003). *Assessment and Management of Central Auditory Processing Disorders in the Educational Setting: From science to practice (2nd ed.).*Clifton Park, NY : Thomson/Delmar Learning.

Bryden, M.P., Munhall, K., & Allard, F. (1983). Attentional biases and the right-ear effect in dichotic listening. *Brain and Language, 18*, 236-248.

Committee on the Rights of the Child (the United Nations) (2005). *Implementation of the Convention of the Rights of the Child: Hong Kong Special Administrative Region Government's Response to the List of issues to be taken up by the United Nations Committee on the Rights of the Child in connection with the consideration of the second periodic report of CHINA (CRC/C/83/Add.9, Part I and Part II).* Retrieved April 12, 2006 from the United Nations website http://www.ohchr.org/english/bodies/crc/docs/AdvanceVersions/HKreply_E.pdf

Cowell, P. & Hugdahl, K. (2000). Individual differences in neurobehavioral measures of laterality and interhemispheric function as measured by dichotic listening. *Developmental Neuropsychology, 18*, 95-112.

Chermak, G.D. & Musiek, F.E. (1997). *Central Auditory Processing Disorders: New perspectives.* San Diego: Singular Publishing.

Fuente, A. & McPherson, B. (2005). Cantonese Dichotic Digits Test [CD]. University of Hong Kong.

Harlpern, D. F. (2000). *Sex Differences in Cognitive Abilities.* New Jersey: Lawrence Erlbaum Associates.

Hällgren, M., Larsby, B., Lyxell, B., & Arlinger, S. (2001). Cognitive effects in dichotic speech testing in elderly persons. *Ear and Hearing, 22,* 120-129.

Hong Kong Census and Statistics Department (2001). *Summary Statistics of District Council Districts in 2001 Population Census.* Retrieved April 27, 2006 from the Hong Kong Census and Statistics Department website http://www.censtatd.gov.hk/hong_kong_statistics/

Hugdahl, K. & Andersson, L. (1986). The "forced-attention paradigm" in dichotic listening to CV-syllables: A comparison between adults and children. *Cortex*, 22, 417-432.

Keith, R. W. (1999). Treatment for central auditory processing disorders: Clinical issues in central auditory processing disorders. *Language, Speech, and Hearing Services in Schools, 30,* 339-344.

Keith, R.W. (2000). Diagnosing central auditory processing disorders in children. In R.J. Rose, M. Valente, & H. Hosford-Dunn, (Eds). *Audiology: Diagnosis.* New York: Thieme Medical Publishers.

Keith, R.W. (2001). Treatment for central auditory processing disorders: Clinical issues in central auditory processing disorders. *Language, Speech, and Hearing Services in Schools*, *30*, 339-344.

Kimura, D. (1961). Cerebral dominance and the perception of verbal stimuli. *Canadian Journal of Psychology*, 15, 166-171.

Kimura, D. (1963). Speech lateralization in young children as determined by an auditory test. *Journal of Comparative and Physiological Psychology*, *56,* 899-902.

Li, W. Y. K. (2003). *Questionnaire-Based Screening for Hearing Disability in Hong Kong School Children.* Bachelor of Science (Speech and Hearing Sciences) dissertation. The University of Hong Kong.

Lysons, K. (1996). *Understanding Hearing Loss.* London: J. Kingsley Publishers.

Molfese, D. F. & Segalowitz (1988). *Brain Lateralization in Children: Developmental Implications.* New York: Guilford Press.

Musiek, F.E. (1983). Assessment of central auditory dysfunction: the dichotic digit test revisited. *Ear and Hearing, 4,* 79-83.

Musiek, F., Gollegly, K., Kibbe, K., Verkest-Lenz, S. (1991). Proposed screening test for central auditory disorders: Follow-up on Dichotic Digits test. *American Journal of Otology, 12,* 109-113.

Neijenhuis, K., Tschur, H., & Snik, A. (2004). The effect of mild hearing impairment on auditory processing tests. *Journal of the American Academy of Audiology, 15,* 6-16.

Neijenhuis, K., Stollman, M., Snik, A., & Broek, P. (2001). Development of a central auditory test battery for adults. *Audiology, 40,* 69-77

Oldfield, R. C. (1971). The assessment and analysis of handedness: The Edinburgh Inventory. *Neuropsychologia, 1,* 97-113.

Phillips, D.P. (1995). Central auditory processing: view from auditory neuroscience. *American Journal of Otolaryngology, 16*, 338-352.

Strouse, A., Wilson, R. H. & Brush, N. (2000a). Effect of order bias on the recognition of dichotic digits in young and elderly listeners. *Audiology, 39,* 93-101.

Strouse, A., Wilson, R. H. & Brush, N. (2000b). Recognition of dichotic digits under pre-cued and post-cued response conditions in young and elderly listeners. *British Journal of Audiology, 34*, 41-51.

Zaidel, E., Aboitiz, F., Clarke, J., Kaiser, D., & Matteson, R. (1995). Sex differences in interhemispheric relations for language. In F. L. Kitterle, (Ed). *Hemispheric Communication: Mechanisms and models.* New Jersey: Lawrence Erlbaum Associates.

Appendix A, Instructions for Cantonese Double DDT

TEST INSTRUCTIONS

<u>Free Recall Test</u>

(English)

You will hear some digits in sets of 4 digits. Each ear will hear 2 of them. After hearing to a set of 4 digits, Please tell me all of them. Let's try.

--Practice Trials x 3--

Very good. Let's start.

(中文)

你會聽到一 o 的數目字, 每組有四個數目字, 每邊耳仔會聽到兩個。

聽完一組數目字之後, 請你講晒四個數目字比我聽。

準備好未呀? 我地 o 黎試下先!

--Practice Trials x 3--

做得好好, 我地開始咯喎!

<u>Directed Left Test / Directed Right Test</u>

(English)

This time, please only tell me the two digits you heard from the left (right) ear?.

Raise up your left (right) hand now. Correct. (Incorrect, Raise your left hand now).

You could ignore the digits you heard on the other side.

Are you ready? Let's try.

--Practice Trials x 3--

Let's start.

(中文)

今次, 試下講我知左 (右)邊 o 既兩個數目字係乜野。你舉一舉左 (右) 手比我睇下! 係喇, (唔係喎, 再舉一次左手比我睇)。你可以唔理另外果邊耳仔聽到 o 既兩個數目字。準備好未呀? 我地 o 黎試下先!

--Practice Trials x 3--

做得好好, 我地開始咯喎!